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Research Paper

Levels of Trace Elements in Plant Parts of Two Cultivars of Wheat at Some Selected Growth Stages

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ABSTRACT

This study was focused on assessment of metals accumulation in plant parts (leaves, stems and roots) of *Triticum aestivum* L. at some selected growth stages at certain distances from the Kano-Zaria road in Kano State, Nigeria. The plant parts of the two cultivars of wheat and their corresponding soil samples were collected during the growing season of 2008/2009 at different sites selected based on traffic density and distances. The levels of Cd, Pb and Zn in the leaves, stems and roots samples of the wheat cultivars and their corresponding soil samples in triplicates were determined by two analytical techniques. Cd and Pb were determined by double beam atomic spectrophotometry while Zn was determined by the energy dispersive X-ray fluorescent (EDXRF). Results showed that the selected growth stages had a significant influence on the metal levels in wheat varieties at both sites. The experimental site closest to the Kano-Zaria highway had higher levels of Cd, Pb and Zn than at the control site. Concentrations of Cd, Pb and Zn at both sites exceeded the permissible limits of the Codex Alimentarius Commission of the Joint FAO/WHO food standards (2006). This study highlights the potential risks of consumption of *Triticum aestivum* L. at close proximity to the highway

Keywords: Triticum aestivum, metals, leaf, stem, root, growth stages, traffic density, Kano- Zaria Highway

INTRODUCTION

Determination of chemical composition of plants is one of the most frequently used methods of monitoring environmental pollution (Lawal *et al*., 2011). Excessive accumulations of heavy metals in agricultural systems through traffic emissions, may results in soil contamination and elevated heavy metal uptake by crops, and thus, affect food quality and safety (Garcia and Millan, 1998; Lawal *et al*., 2011). The situation is further exacerbated by the reality of increasingly large-scale importation of old or fairly used vehicles for use on the Nigerian highways (Alo, 2008). Among toxic metals, Pb and Cd are the most toxic and the most abundant heavy metals in food and the most dangerous to the environment (Khan *et al*., 2009). Cadmium (Cd) is already considered one of the most toxic heavy metals that are harmful to mankind because of high ambulation (Huang *et al*., 2004). Cadmium (Cd) inhibits growth of plant root (Belimov et al., 2003), uptake of water and nutrients (Boussama *et al* et al., 1999), photosynthesis (Krupa and Miniak, 1998) and respiratory vigor (Bazzaz *et al*., 1974), affecting carbohydrate metabolism and other physiological aspects, and thereby reducing yield (Verma and Dubey, 2001; Sandalio *et al*., 2001). These effects could get worse with increasing Cd concentration. Lead (Pb) can also be accumulated in roots, shoots and leaves after being absorbed by plants (Morelli and Scarano, 2001).

Metal pollution in developing countries especially in semi-arid zones is of great concern because 80% of irrigated wheat cultivated by farm families in the rural areas is circulated for consumption within (Abba, 1990) and outside Kano state. Wheat cultivation in Nigeria started long before the colonial time particularly in Mai Alkama area of Hadejia local government. Its cultivation in this area started declining after the construction of the Tiga Dam, when the amount of flood in the Hadejia Valley declined (Abba, 1990). Commercially, wheat cultivation in Nigeria is entirely by irrigation and presently restricted to areas located within latitudes 10^{o}-14^{o}N and altitude of 240 – 306m (Odo and Adamu, 1990), mainly the Sudan and Sahel zones where night temperatures are low enough during the growing season (Olugbemi *et al*., 1990). There is little evidence in Nigeria that productive crop system are sensitive to atmospheric deposition, since the impacts of air pollutants on crop production as well as the economic significance is likely of greatest concern in most developing countries. It is therefore important to highlight the role of toxic metals in food chain contamination and the attendant health risks of edible parts of metal contaminated food crops either consumed directly or when the vegetative parts are fed to livestock that are subsequently used as sources of animal protein and food in human diet.

MATERIALS AND METHOD

Study Site: The study was conducted around a major highway in Kano state, Nigeria. The soil and plant samples were collected at the Irrigation Research Station and Doruwa Salau at distances of 2,438.28m and 345.79m from the highway respectively. Wheat (*Triticum aestivum*L.) var. Siettecerros and Pavon-76 grown during the 2008-2009 harmattan growing season at some selected distances perpendicular to the Kano-Zaria highway, a major highway with an average daily traffic density of 19,288 vehicles were used for this study. The plant and corresponding soil samples were collected at six selected growth stages namely the 15-days, 30-days, 45-days, 60-days, 75-days and 90-days growth stages representing the seedling or germination, tillering, shooting or booting, heading and earing, flowering and ripening stages respectively. Two varieties of wheat (*Triticum aestivum*L.) var. Siettecerros and Pavon-76 were obtained from the Irrigation Research Station, Kadawa and Kano State for this study.

Analysis For lead (Pb) Double Beam Atomic Spectrophotometer: 1 g of ground dried plant sample was weighed into a digestion vessel. 10 mL of concentrated HNO_3 was added into it and allowed to stand overnight. The mixture was carefully placed on a hot plate and heated for 4 hours at 125^0C until the production of red NO_2 fumes has ceased and the entire solids has disappeared and a transparent solution is obtained. Next, HCl and distilled water in a ratio of 1:1 was added to the digested sample and the mixture transferred to the digester again for 30 mins. The beaker was then removed from the hot plate and allowed to cool. A small amount (2-4 mL) of 70% $HClO_4$ was added, heated slowly at a low temperature and allowed to evaporate to a small volume. The cooled sample was then transferred into a 50-mL flask and diluted to the appropriate volume with distilled or deionised water and filtered through filter paper No 1. Determination of heavy metals was done in double beam atomic absorption spectrophotometer (model Shimadzu AA 650) after calibrating the equipment with stock standard solution of 1000 mg/L for Cd, 1.000 g of cadmium metal was dissolved in a minimum volume of (1+1) HCl and diluted to 1 liter with 1% (v/v) HCl while, the stock standard solution of 1000 mg/L for Pb was prepared by dissolving 1.598 g of lead nitrate -$Pb(NO_3)_2$- in 1% (v/v) HNO_3 and diluted to 1 liter with 1% (v/v) HNO_3. The acid digestion produces a clear solution without loss of any of the elements to be determined. A combination of nitric acid and perchloric acid is especially useful for the complete destruction of fats and proteins in biological samples (Amoo *et al.,* 2004).

Zinc (Zn) Analysis by EDXRF: Pellets of 19mm diameter were prepared from 0.3-0.5g powder mixed with three drops of organic liquid binder and pressed afterwards at 10 tons with a hydraulic press. Measurements were performed using an annular 25m Ci^{109} Cd as the excitation source that emits Ag-K X-rays. (22.1kev) in which case, all elements with lower characteristic excitation energies were accessible for detection in the samples. The system consists furthermore of a Si (Li) detector, with a resolution of 170 eV for the 5.90 kev line, coupled to a computer controlled ADC-card.

Quantitative analysis of the samples was carried out using a modified version of E-T method (Kump, 1996, Angeyo*et al.,* 1998; Funtua, 1999a; Funtua, 1999b) and it involves the use of pure target material (Mo) to measure the absorption factors in the sample. The Mo target serves as a source of monochromatic X-rays, which are excited through the sample by primary radiation and then penetrate the sample on the way to the detector. In this way, the absorption factor is experimentally determined which the program uses in the quantification of concentration of the elements. In addition, the contribution to the Mo-K peak intensity by the Zr-K is subtracted for each sample. Sensitivity calibration of the system was performed using thick pure metal foils (Ti, Fe, Ni, Cu, Zn, Zr, Nb, Mo, Sn, Ta, Pb,) and stable chemical compounds ($K_2CO_3Ca\ Co_3$, Ce_2O_3, ThO_2, U_3O_8). The spectra for the samples were collected for 3000 seconds with the ^{109}Cd source and 2000 seconds for the ^{55}Fe source and the spectra were then evaluated using the AXIL-QXAS program (Bernasconi, 1996). ^{109}Cd source was used for the analysis of K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Ca, Zn, Ta, W, Ga, As, Se, Pb, Br, Rb, Sr, Tn, Y, U, Zr, Nb and Mo.

RESULTS AND DISCUSSION

Figures 1, 2 and 3 show the mean concentrations of Lead (Pb), Cadmium (Cd) and Zinc (Zn) at some selected growth stages in the leaves, stems, roots and soil samples of the two cultivars of wheat. The magnitude of the metals detected in the samples from the experimental and control sites was Pb>Zn>Cd (Figs 1, 2 and 3).

Figure 1. Levels of Lead (Pb), Cadmium (Cd), and Zinc (Zn) in the leaves of Siettecerros (SU 2) and Pavon-76 (SU1) among the selected growth stages

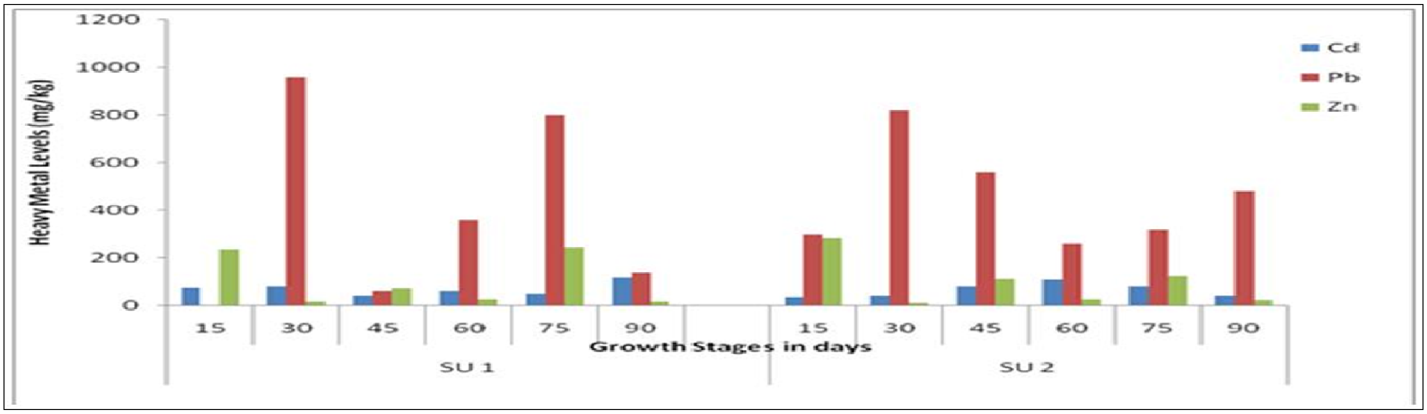


Figure 2. Levels of Pb, Cd and Zn in the stems of Sietecerros (SU2) and Pavon-76 (SU1) among the selected growth stages

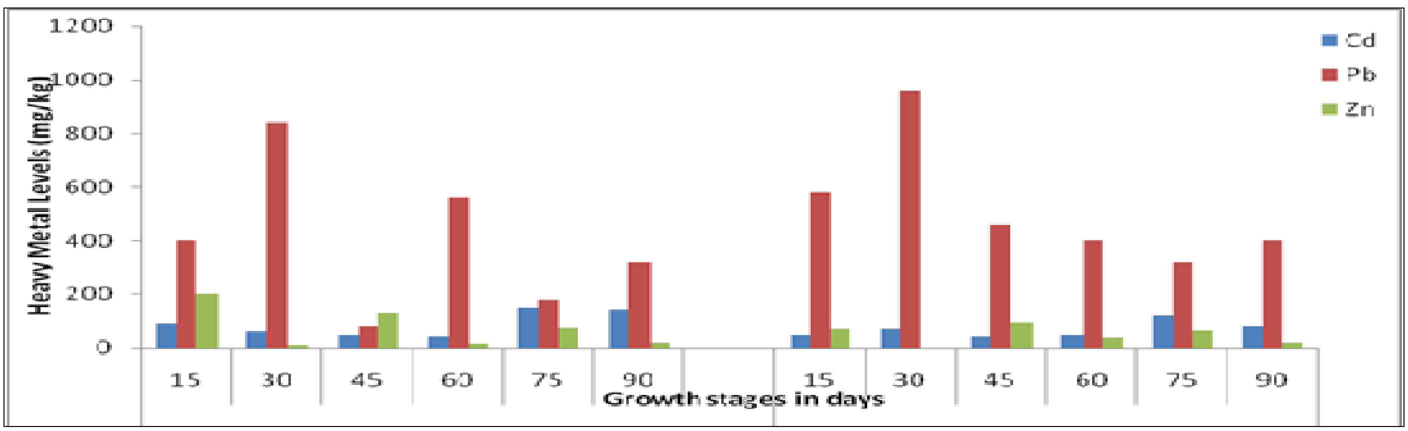
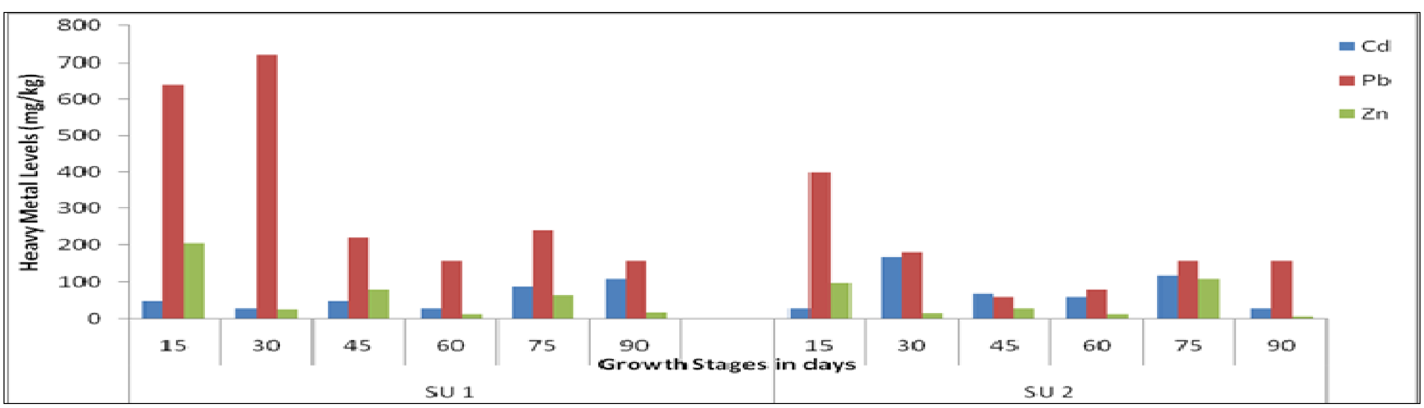


Figure 3. Levels of Pb,Cd and Zn in the roots of Siettecerros (SU2) and Pavon-76 (SU1) among the selected growth stages



The mean concentration of Cd ranged from 38.33mg/kg in SU 2 (table 2) at the 15 days growth stage to 123.33mg/kg in SU 1 (table 1) at the 90 days growth stage. The mean concentration range of Pb was 120mg/kg to 840mg/kg, with both the highest and lowest concentrations obtained from SU 1 at the 30 and 45 days respectively (table 1). The mean concentration of Zn ranged from 9.91mg/kg to 213.77mg/kg with the highest concentration from SU 1 (table 1) and the lowest from SU 2 (table 2) at the 15 and 30 days growth stages respectively. Also among the three metals investigated, Pb had the highest levels both at the experimental and control sites followed by Zn, then Cd.

Generally, samples from SU 1 showed highest concentrations of Cd, Pb and Zn than at SU 2, table 3 and 4. High concentrations of Cd, Pb and Zn at SU 1 are due to its close proximity to the Kano-Zaria highway. It could also be

Table 1. Mean Whole Plant Metal Concentrations at the Experimental Site (SU 1) among the selected growth stages

Growth Stages (days)	Mean Whole Plant Metal Concentrations at the Control site (SU 2)		
	Cd	Pb	Zn
15	71.66	346.66	213.77
30	56.66	840	18.23
45	46.66	120	95.27
60	43.33	360	18.75
75	96.66	406.66	127.70
90	123.33	206.67	18.42

Table 2. Mean Whole Plant Metal Concentrations at the Control Site (SU 2) among the selected growth stage

Growth Stages (days)	Mean Whole Plant Metal Concentrations at the Control site (SU 2)		
	Cd	Pb	Zn
15	38.33	426.67	151.15
30	93.33	653.33	9.91
45	63.33	360	77.80
60	73.33	246.67	26.62
75	106.67	266.67	99.27
90	50	346.67	17.36

attributed to the high traffic density due to absence of industrial and commercial activities within the vicinity of the sampling site. A low concentration of Cd, Pb and Zn on the control site (SU 2) at a perpendicular distance of 1934.61m from the highway could be related to the sampling site being farthest from the highway. However, the levels of these metals are above the permissible limits (Cd = 0.01mg/kg; Pb = 0.1mg/kg; Zn = 5.00mg/kg) recommended by the Joint FAO/WHO Codex Alimentarius (2006), particularly at SU 2 which could be related to the far distance transport of these particulate metals (Mutsch, 1996).

Table 3: Analysis of variance for SU 1

Source of Variations	Heavy Metal	DF	SS	MS	F-RATIO	SIGN.	
Plant Parts (P-1)	Cd	2	2452.78	1226.39	2.1526	NS	NS
	Pb	2	5200	2600	0.0447	NS	NS
	Zn	2	3802.19	1901.09	1.0034	NS	NS
Growth Stage (G-1)	Cd	5	14806.95	2961.39	5.1979	NS	*
	Pb	5	934400	186880	3.2154	NS	NS
	Zn	5	95214.96	19042.99	10.0510	**	*

Table 4: Analysis of variance for SU 2

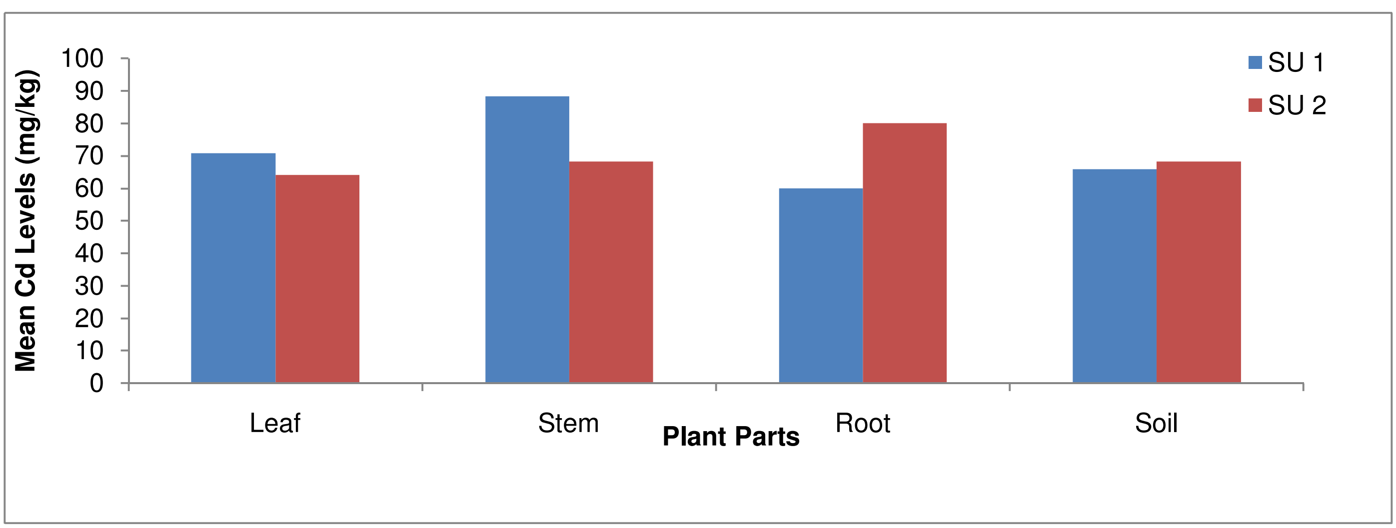
Source of Variations	Heavy Metal	DF	SS	MS	F-RATIO	SIGN.	
Plant Parts (P-1)	Cd	2	808.33	404.16	0.2871	NS	NS
	Pb	2	408933.33	204466.66	8.4770	**	*
	Zn	2	10095.24	5047.62	2.1906	NS	NS
Growth Stage (G-1)	Cd	5	10029.16	2005.83	1.4251	NS	NS
	Pb	5	326866.66	65373.33	2.7103	NS	NS
	Zn	5	46578.13	9315.62	4.0429	NS	*

Therefore by implication, the rural families living along this highway and other highways in Nigeria especially in northern Nigeria, are exposed to a high potential health risks associated with these metals as well as the potential transfer of these metals from livestock to man, when the forages are used as animal feeds. It also posed a potential risk to the soil and its organisms as the remnants of the cereals are left to form composts by mulching for the next growing season, thereby releasing these metals into the soil.

Furthermore, there was no significant difference in the Pb levels at SU 1 and was highly significant (P=0.05 and 0.01) at SU 2 all among the growth stages suggesting that the Pb levels at SU 1 was not influenced by the growth stages but by the proximity to the highway. Whereas at SU 2, Pb levels was greatly influenced by the plant parts, growth stages, variety of the wheat as well as the distances from the highway than at SU 1. Cd was significant (P=0.05) for the growth stage at SU 1 only which indicates that the levels of Cd in Pavon-76 could be a potential threat to human and livestock. Also Zn levels was highly significant (P=0.05 and 0.01) at the growth stage too for both varieties of *Triticum aestivum* . This reflects that the growth stages rather than the plant parts greatly influenced the levels of Cd, Pb and Zn in these varieties (Pavon-76 and Siettecerros) of *Triticum aestivum*.

Metal accumulation by plants is influenced by the variations in plant species, the growth stages of the plants, element characteristics, control absorption, accumulation and translocation of metals (Nouri *et al*., 2009). It is also a known fact that metal sensitivity and toxicity to plants are influenced by not only the concentration and the toxicant types but are also dependent on several developmental stages of the plants (Liu *et al* et al., 2005; Hatamzadeh *et al*., 2012). Plants differ in their uptake of heavy metals and the subsequent distribution of metals within the plant organs (Pal *et al*., 2013). Comparison among the plant parts shows that the leaves accumulated higher levels of Pb, Zn and Cd than the stems and roots in this study.

Figure 4: Mean Cd Levels (mg/kg) in the soil and among the plant parts of Triticum aestivum at the experimental (SU 1) and control (SU 2) sites



Wheat metal (Cd, Pb) levels in the above ground parts were generally higher than soil Cd and Pb as shown in figs 4 and 5. Root Cd was the lowest among the plant parts in figure 4. In figure 5, mean Pb in the plant parts was higher than soil Pb, whereas soil Zn was higher than Zn levels in the leaf, stem and root (figure 6). This is a strong indication that the higher metal levels in the plant parts are anthropogenic arising from long term emissions of motor vehicles (Momani *et al*., 2000) and not from parent materials (Donisa *et al*.,2000). However, the high Zn levels in the soil than in the above ground parts may have been further enriched by the particulate atmospheric deposition

Figure 5: Mean Pb Levels (mg/kg) in the soil and among the plant parts of Triticum aestivum at the experimental (SU 1) and control (SU 2) sites

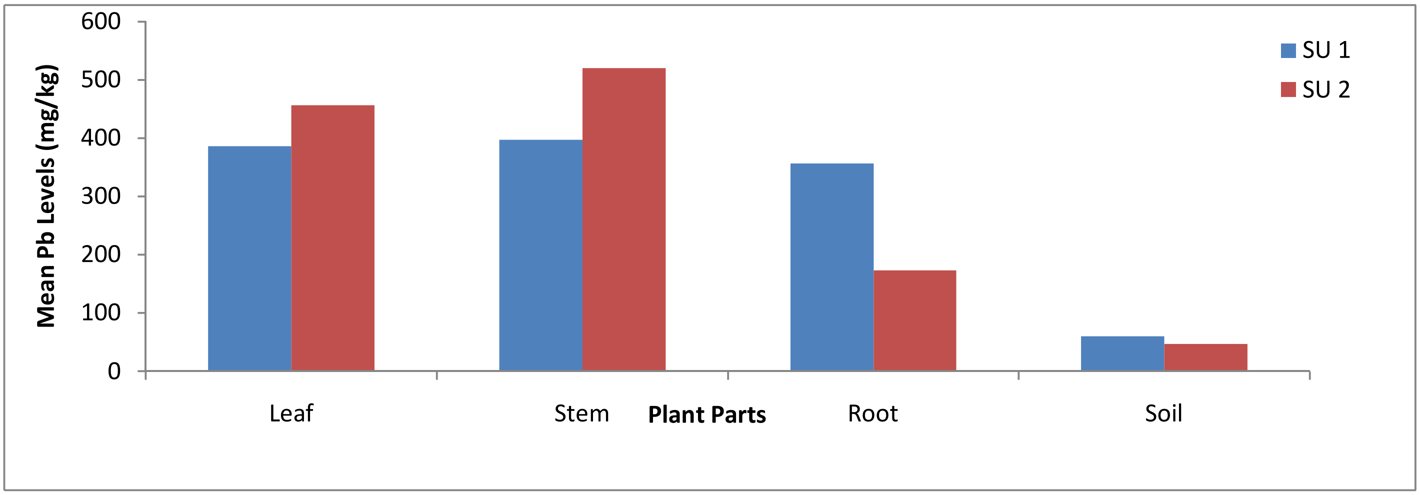
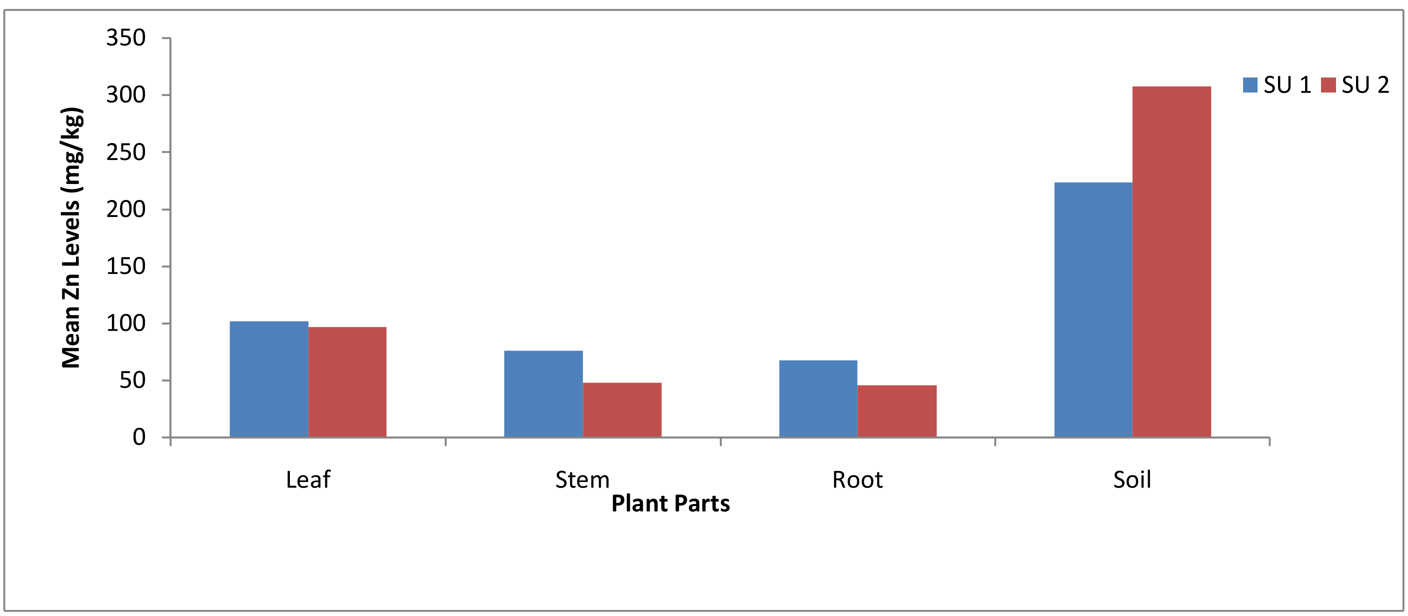


Figure 6: Mean Zn Levels (mg/kg) in the soil and among the plant parts of Triticum aestivum at the experimental (SU 1) and control (SU 2) sites



CONCLUSION

In this study, the selected growth stages had a significant influence on the heavy metal levels in the two varieties of wheat cultivated at the different distances from the Kano-Zaria highway. The leaves had higher levels of Cd, Pb and Zn than in the stems and roots indicating atmospheric deposition. Also the experimental site (SU 1) at close proximity to Kano-Zaria highway had higher levels of Cd, Pb and Zn than at the control site also indicating atmospheric inputs. Concentrations of these metals at both sites exceeded the permissible limits of the Joint FAO/WHO food standard (2006).

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